Assembly, Integration and Testing of Special Tests of Chandrayaan-3

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***Abstract* — The mission objective of Chandrayaan-3 was to design, realise and deploy a lunar Lander-Rover capable of soft landing on a specified lunar site and deploy a rover to carry out in-situ analysis of chemicals. Number of tests were planned namely Integrated Cold Test(ICT), Integrated Hot Test(IHT) and Hardware simulator to evaluate the sensors and actuators of lander module. This paper briefly explains the assembly, integration and testing of the module for different special tests proposed to validate the overall performance of the system which was crucial for the safe and successful landing on lunar surface.**

Keywords — Chandrayaan-3 Spacecraft; Special tests; Assembly, Integration and Testing; Sensors; Actuators; NGC

I. INTRODUCTION

Chandrayaan-3 consists of set of sensors, actuators and NGC system that operate in closed loop to achieve the mission objective of safe and successful landing on lunar surface. The integrated performance validation of all the sensors and actuators on ground along with navigation, guidance and controls was major requirement towards successful realisation of the mission. The module used to conduct these tests were scaled down model of Lander which was suitably designed to be tested in Earth environment. The sensors and actuators were mounted on this scaled down model of Lander which was flown in a simulated test profile over the artificially created test sites (artificial lunar craters).

Integrated cold test(ICT) was done to validate the performance of sensors and NGC. Integrated Hot Test(IHT) was to assess the integrated performance of the propulsion system, sensors and NGC in closed loop environment. Hardware Simulator test was done to validate the closed loop dynamics testing of flight equivalent hardware along with its software. In this test,Lander-Module sensors and TECEM with NGCE were tested which were used during the descent trajectory.

II. SPECIAL TESTS

Integrated Cold Test(ICT), Integrated Hot Test(IHT) and Hardware Simulator Test were the three specials tests conducted to evaluate the hardware and software designed for soft landing of Lander.

A. Integrated Cold Test

The lander module of Chandrayaan-3 consists of set of sensors (KaRA (Ka Band Radio Altimeter) with DPU (Digital processing unit), LPDC (Lander position Detection Camera), Lander Hazard Detection and avoidance Camera(LHDAC), Laser Inertial Reference and Accelerometer Package(LIRAP), Laser Altimeter (LASA), Lander Horizontal Velocity Camera(LHVC) and LDV) which aids for safe and successful landing on lunar surface. The main objective of ICT was to validate the integrated performance of all these sensors. In this test, Helicopter was selected as a test platform which was used to validate the integrated performance of sensors along with NGC from an altitude of 2.5km to 10m including hovering at required altitude of 800m and 150m.In addition to identified helicopter, aircraft was used to validate the performance of altimeters at higher altitude. Validation of navigation (GPS-SPAN) was done with helicopter navigation to carry out the test

All these sensors were validated in ICT. LEP, and Power system were the supporting systems.

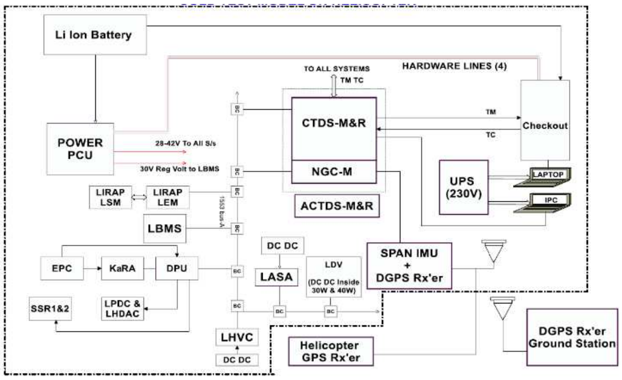

Figure 1: Overall Electrical Configuration

Assembly and Integration of ICT module: The major activities include mechanical integration, electrical integration, system level tests and EMI/EMC test at integrated level. These tests were carried out in URSC cleanroom namely

- Assembled phase IST
- Alignment test
- EMI/EMC checks

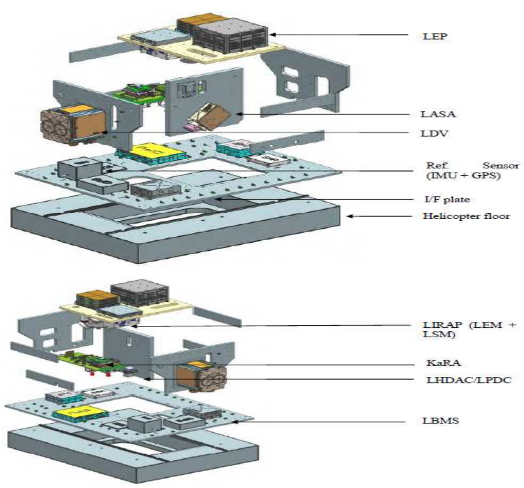

Figure 2: Exploded view of test module.

a) Assembled Phase IST: During Assembled Phase IST, functional verification of each system and interfaces between systems will be verified. All the systems were assembled after establishing electrical interconnections in the final form. In this phase, detailed testing is carried out and corrected test procedures are taken as the reference. Sequence of events(SOE) was executed as per required timeline to have reference for field test. This test was done on on-board battery to establish battery endurance.

b) Alignment test: Alignment of all sensors was completed at URSC. However, after integration of test module inside helicopter, alignment of complete test module w.r.to helicopter was carried out.

c) EMI measurement: Radiated Emissions: This requirement is applicable for all the subsystems to be installed on helicopter and associated cables and interconnecting wiring of the test sample. Ambient scans were taken with subsystems OFF and ground support instrumentation ON. This data provided means to separate ambient background noise from subsystem emissions.

d) Activities done at ASTE, Bengaluru:Major activities conducted at ASTE were:

- De-containerisation of test module and allied equipment
- Assembly of test module, checkout rack with helicopter
- Replacement of helicopter GPS antenna with ISRO's GPS antenna
- Establishment of GPS ground station
- Functional Test of all sensors and electronics
- Ground run and shake-down sortie

After completion of above activities, Test module was integrated with helicopter followed by checkout rack mounting in helicopter. UPS/Checkout unit/IPS was mounted on checkout rack after assembly of rack with helicopter. GPS antenna was replaced with existing helicopter GPS antenna. All electrical interconnections for test module, checkout,battery,IMU/GPS was established. Subsequent to completion of all assemblies with helicopter and establishment of ground station for GPS,following sequence of activities was carried out prior to shifting of ATR.

- Establishment of external power supply
- Functional test of test module using hangar power supply
- Switch ON of all active systems using UPS supply and battery
- Functional test of test module using hangar power supply
- Ground run
- EMC measurement by ASTE team
- Shake down sortie
- Charging of UPS using external power supply
- Disconnecting external supply from hangar
- Helicopter was flown to ATR with module in ON condition after clearance from our team

B. Integrated Hot Test(IHT)

Integrated Hot Test was planned to evaluate the closed loop performance of above systems. Static test were also planned validate propulsion system performance by anchoring the module to ground in addition to dynamic tests.

The module consists of structure, propulsion system, Sensors (LIRAP, LASA, KaRA, LDV, LHVC and LHDAC), NGC & TCTM (LEP &NEP), power system, checkout system, thermal protection, RF system, reference sensor (SPAN IMU, GPS) and associated elements.

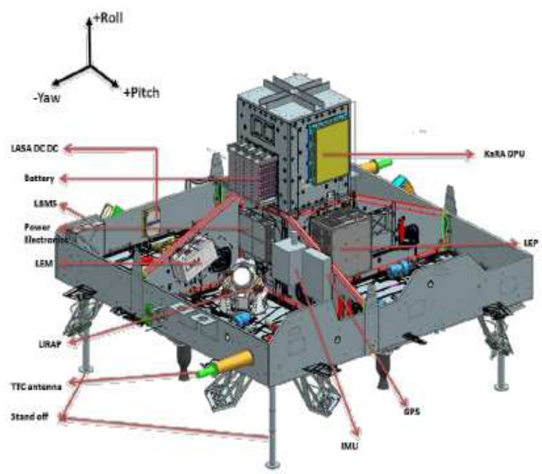

Figure 3: IHT module

In IHT,4 types of tests were performed namely Dry run tests (DRT 1), Static Tests (ST 1), Dynamic Tests (DT 1), Static test (ST 2). These tests are briefly explained below.

a) *Dry Run tests (DRT):* The dry run tests were carried out to test the sensors of IHT module before start of dynamic test.

b) *Static Tests(ST1):* These Static tests were carried out to test propulsion system before start of dynamic tests of IHT.These tests are open loop tests carried out by anchoring the module to the ground.

c) Dynamic tests(DT): The objectives of dynamic tests were to access the integrated performance of the Propulsion system, Sensors and NGC in closed loop environment. These tests were planned to demonstrate hovering and vertical descent with sensors, NGC and actuators in closed loop.

d) *Static tests (ST 2*): The objective of IHT static tests-2 were to evaluate propulsion system performance for a compact mission profile and to capture propulsion system signatures for deboost profile These static tests were performed after necessary modification of orifices required to meet the chamber pressure of liquid engines identical to flight. Four-point handling was during test preparatory activities and single point handling was used for pre-test, test and post-test operations

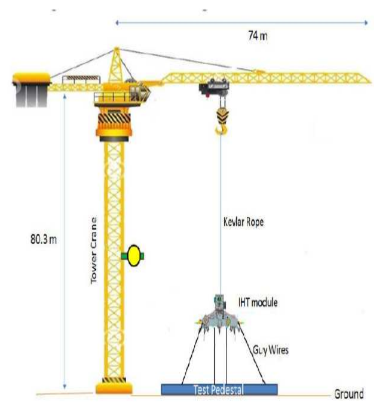

Figure 4: Test set up for static test

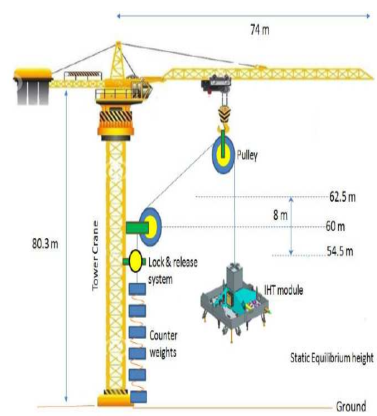

Figure 5: Test set up for dynamic test

Battery Charging Console was stationed in control room and harness from the rack was routed from the rack to the module along with the hardwired line.

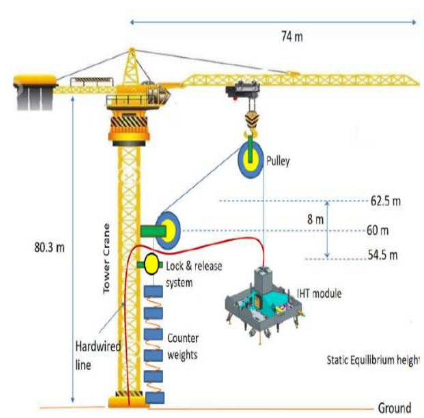

Figure 6: Hardwired line to IHT module

a) Activities in cleanroom: All the subsystems including propulsion system were integrated to IHT module and all the hardwired interfaces were checked during integration phase. During assembled phase IST, functional verification of each system and interfaces between systems was verified. In this phase, detailed testing is carried out and corrected test procedures were taken as reference.

b) Activities at test site: Initial preparatory activities at test site before test.

- Establishment of GC equipment and RF antenna in control room, T&E and clearance.
- Establishment and verification of link between control room ad module service room
- Battery charging of the module
- Establishment and verification of hard line interface between control room and test pedestal.
- Power on of the module and cursory checks post transportation.
- Alignment
- Propulsion system preparatory activities and pressure hold test
- Propellant loading
- Pertest GC Checks-Hard lines continuity and RF link
- Final finishing of thermal tape

c) Activities at test pedestal before test

- Connection of hard line interface and battery charging interface to the module
- Mating of connectors (Battery, umbilical and propulsion)
- Clearance for module power on.

d) Pre-test, test and post-test activities at test pedestal

- Power On of the module and. verification of RF link from control to the module.
- Configuration of DAS, KaRA, SSR, SPAN-GPS-IMU
- Calibration of LIRAP before start of the test.
- Continuation of test SOE
- Commencement of test
- Power off after completion of the test
- Disconnection of battery, thrusters and hard line interface connectors
- Movement of module inside Module service room

C. *Chandrayaan Spacecraft Hardware Simulator(CSHS)*

CSHS incorporates the hardware simulators for propulsion module(PM), Lander module(LM) and Rover. It consists of Chandrayaan-3 LM hardware Simulator(CLHS), Chandrayaan-3 PM hardware Simulator(CPHS) and rover system.CLHS incorporates the Flight Equivalent Sensor Hardware, NGCE, CTDS, Power Systems and Actuator Hardware (each subsystem with its flight software) with Lander electronics package (LEP)-test system (that simulates spacecraft dynamics, provides stimuli measurement interfaces and flight equivalent integration harness) and Mission SCHEMACS software.

Main objectives of CSHS are as follows

- Closed loop dynamics testing of flight equivalent hardware (along with its software) namely Lander module sensors and TECEM used during descent trajectory with the NGCE.
- Subsystem dispersion assessment e.g. Actuator response tome vis-à-vis control
- Clearance of all the mission procedures and uplinks
- Interface logic checks
- Verification of mission database
- Threshold limit checks
- FDIR and off-nominal logics testing
- Terminate logics
- Integrates Mission Simulator Host, Checkout systems and SCHEMACS systems for activities required to be carried out in different phases of the project.

III. CONCLUSION

This paper briefly outlines assembly, integration and testing procedures for different types of tests namely IHT, ICT and CSHS which were crucial for the successful soft landing of lander on the moon surface. These tests were done to validate the hardware and software for different phases of the Chandrayaan-3 mission. The observations found in these tests were corrected and implemented on flight hardware and software.

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